Spitzer Observations of η Corvi : Evidence at ~1 Gyr for an LHB-Like Delivery of Organics & Water-Rich Material to the THZ of a Sun-Like Star.

C.M. Lisse[1], C. H. Chen[2], M. C. Wyatt[3], A. Morlok[4], P. Thebault[5], G. Bryden[6], D.M. Watson[7], P. Manoj[7], P. Sheehan[7], G. Sloan[8], T.M. Currie[9] [1]JHU-APL, 11100 Johns Hopkins Road, Laurel, MD 20723 carey.lisse@jhuapl.edu [2]STScI [3]IoA, Univ of Cambridge, Madingley Road, Cambridge CB3 0HA, UK [4]PSSRI, The Open University, Milton Keynes, MK7 6AA [5]Observatoire de Paris, F-92195 Meudon Principal Cedex, France [6]Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109 [7]Department of Physics and Astronomy, University of Rochester, Rochester, NY 14627 [8]Department of Astronomy, Cornell University, 108 Space Sciences Bldg., Ithaca, NY 14853 [9]Code 667, NASA-GSFC, Greenbelt, MD 20771

Introduction. We have analyzed the Spitzer IRS 5 – 35 um spectrum of the warm, ~360K circumstellar dust around the nearby MS star η Corvi (F2V, 1.4 ± 0.3 Gyr), a known IRAS excess object with a very high 24um excess luminosity for its age (Fig. 1). The Spitzer spectrum (Fig. 2) shows clear evidence for warm, water- and carbon-rich dust at ~ 3 AU from the central star, uncoupled and in a separate reservoir from the system's extended sub-mm dust ring at 150 ± 20 AU [2,3] (Figs. 1 & 3).

Spectral features similar in kind and amplitude to those found for ultra-primitive material in ISO HD100546 spectra were found (water ice & gas, olivines & pyroxenes, amorphous carbon and metal sulfides), in addition to emissions due to impact produced silica and high temperature/pressure carbonaceous phases [4]. A large amount, at least 3×10^{19} kg, of 0.1 – 1000 μm warm dust is present, in a roughly collisional equilibrium distribution with $dn/da \sim a^{-3.5}$. This is the equivalent of a 140 km radius asteroid of 2.5 g cm^{-3} density or a "comet" of 260 km radius and 0.40 g cm^{-3} density. If we allow for particles larger than 1 cm, the mass present increases by (largest particle size/1000 μm)$^{0.5}$, and the equivalent parent body radius increases by the 0.167th power [4].

Findings From the Spectral Analysis:

- The η Corvi system emits > 1000 times as much 24 um flux as other co-eval (~1 Gyr) dusty disk systems.

- The η Corvi system contains an extended belt of cold Kuiper Belt dust (Mass ~ 2×10^{23} kg = 3 M_{Moon}) at ~150 AU from the primary.

- The η Corvi system contains a reservoir of warm (~360K) dust massing > 3×10^{19} kg (~10^{-4} the mass of the Kuiper Belt dust) at ~3 AU from the primary, in the system's Terrestrial Habitability Zone (THZ).

- The warm dust is ***very*** primitive, and definitely not from an asteroidal parent body. It is also very water and carbon rich, and while comet-like, its spectrum matches best the emission seen from the cold, extended dust disk found around HD100546, an ~10 Myr old Herbig A0V.

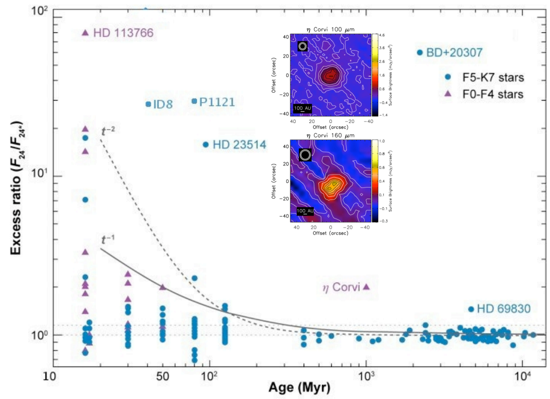

Figure 1 - Dusty disk IR excess luminosity vs time. η Corvi is the 3rd brightest of [1]'s 59 IRAS-excess systems, and the only one which is a "mature" MS system of ~1.4 Gyr age, or about 1/3 of its total MS lifetime. The 1/t and 1/t^2 trend lines fit most of the sources in the current sample except outliers like η Corvi, which clearly has a high $L_{IR}/L_* = 3 \times 10^{-4}$ for its age, suggesting something unusual has occurred in this system. *Inset*: 100 um (top) and 160 um (bottom) Herchel PACS FIR images of the extended bright η Corvi Kuper Belt, after [2]. Contours are shown at 0, 10, 30, 50, 60, 70, 80, 90 and 99% of the peak in the map. Circles in the upper left corner of each panel mark the nominal beam sizes.

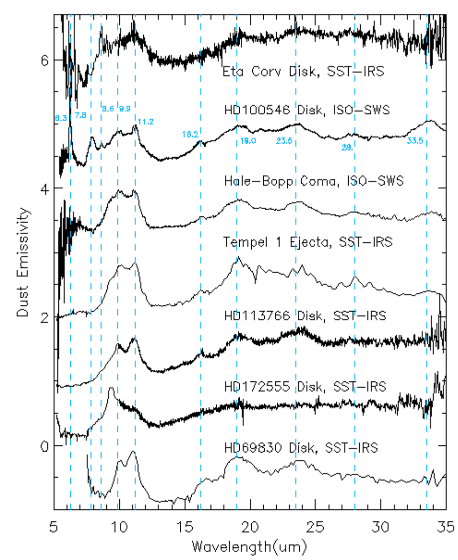

Figure 2 – Comparison of the mid-IR spectra of η Corvi with the spectra of dust from: a young, organic rich Herbig A0 star building a giant planet (HD100546) [5]; two comets (Hale-Bopp and Tempel 1) [5]; a young F5 star building a terrestrial planet (HD113766) [6]; the silica-rich debris created by a hypervelocity impact in the HD172555 system [7]; and a mature main sequence star with a densezodiacal cloud (HD69830) [8]. The similarity between the η Corvi and HD100546 spectra is readily apparent.

- The warm dust mass is much larger than that of a solar system comet (10^{12} – 10^{15} kg), but is very similar to the mass of a large Centaur or medium sized Kuiper Belt object (10^{19} – 10^{21} kg).

- The warm THZ dust also contains a fraction of amorphous silica produced by impact processes.

- The amount of water tied up in the observed material, ~10^{19} kg, is > 1% of the water in the Earth's oceans, & the amount of carbon is also considerable, ~10^{18} kg.

Conclusions. The best model for what is going on in the η Corvi (F2V) system is that some process (*e.g.,* planetary migration) is dynamically exciting the Kuiper Belt, causing frequent collisions amongst KBOs and producing the observed copious KB dust. As part of this process, one or more of the excited KBOs was scattered onto an orbit that sent it into the inner system, where it collided with a planetary-class body at ~3 AU, releasing a large amount of thermally unprocessed, primitive ice and carbon-rich dust.

We conclude that the parent body for the warm dust was a Kuiper-Belt or Centaur-like body, which captured a large amount of early primitive stellar nebula material and kept it in deep freeze for ~1 Gyr, and was then prompted by dynamical stirring of its parent Kuiper Belt into colliding with a planetary body at ~3 AU at moderate velocities (5-10 km sec^{-1}). The interaction velocity was slow enough to preserve most of the original refractory silicates but also fast enough to refreeze ~1/3 of it as silica material, while also delivering large amounts of water (~1% of the mass of Earth's Oceans) and carbon rich material to the planetary body.

This system is likely a good analogue for the LHB processes that occurred in the early Solar System at 0.6 – 0.8 Gyr after the formation of the CAIs, and is thus worthy of further detailed study in order to understand the nature of our LHB. It is also a good system to perform a search for a rocky planetary body at ~3 AU (the impactee), and for a giant planet at ~115 AU (the KB dynamical stirrer at ~ the 3:2 resonance of the KB dust at 150 AU).

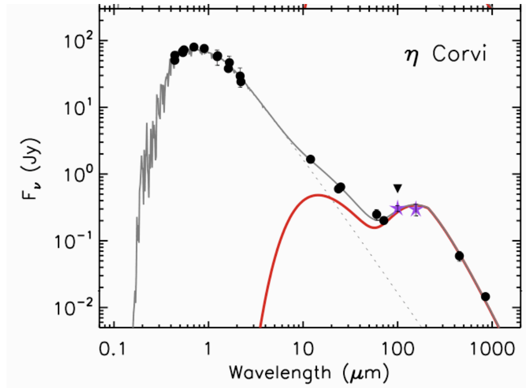

Figure 3. SED for η Corvi showing the 0.4 – 2.2 μm BVR/2MASS system photometry dominated by stellar photospheric emission, the stellar/circumstellar dust MIR flux measurements of IRAS and Spitzer, & the cold FIR excess measured by Herschel and JCMT/SCUBA [2]. Solid grey line: combined fit to the η Corvi SED using a 2-blackbody model (red) with warm (350K) & cold (35K) dust reservoirs + emission from a Kurucz F2V photosphere (dashed line).

References: [**1**] Chen, C. H., *et al.* 2006, *ApJS* **166**, 351; [**2**] Matthews, B.C., *et al.* 2010. *Astron. & Astrophys.* **518**, L135 [**3**] Wyatt, M.C. *et al.* 2005. *Astrophys. J.* **620**, 492; **[4]** Lisse, C.M., *et al.*, 2011. *ApJ* (submitted)**; [5]** Lisse, C.M. *et al.*, 2007, *Icarus* **187**, 69; [**6**] Lisse, C.M. *et al.*, 2008, *ApJ* **673**, 1106 [**7**] Lisse, C.M. *et al.*, 2009, *ApJ* **701**, 2019; [**8**] Lisse, C.M., *et al.* 2007, *ApJ* **658**, 584

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